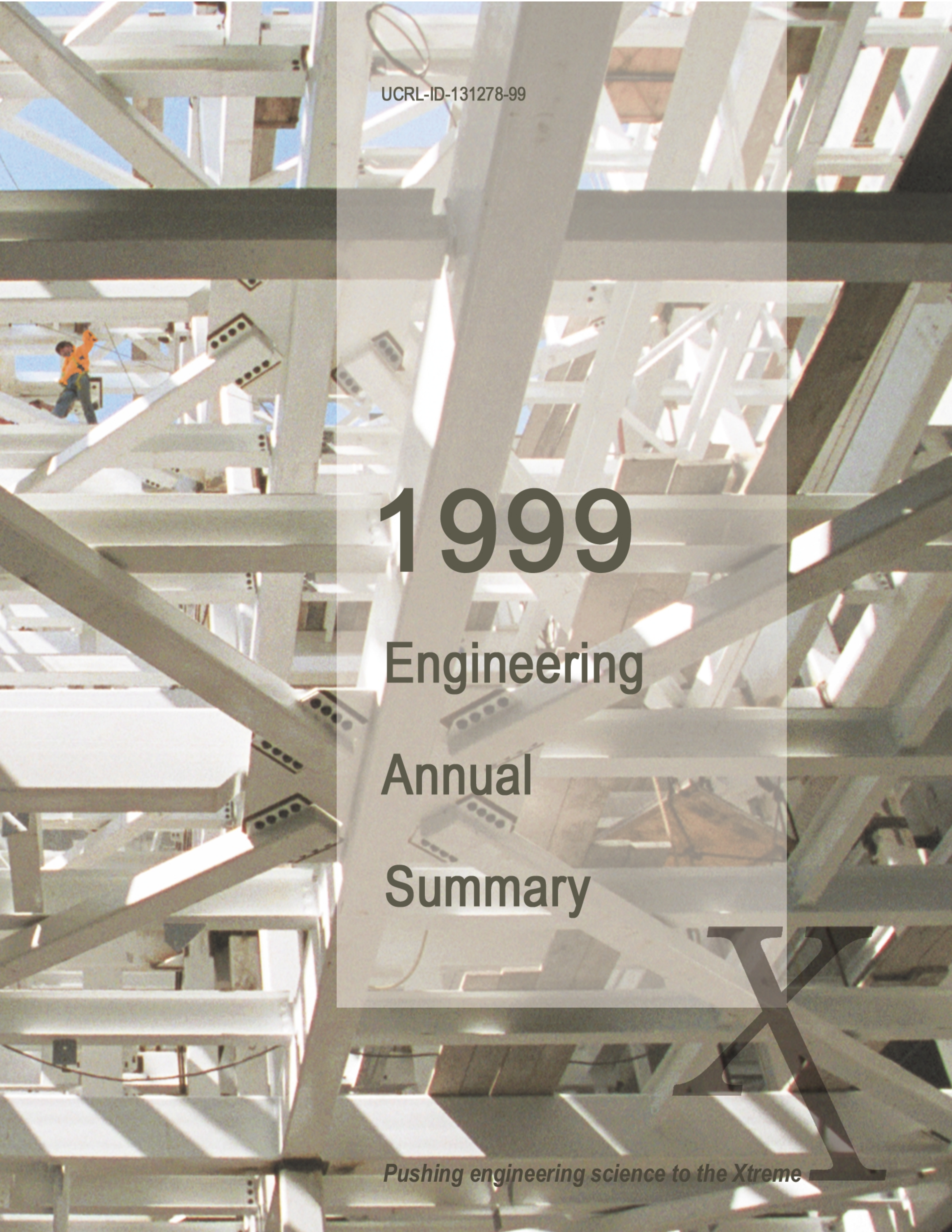


UCRL-ID-131278-99

1999 Engineering Annual Summary

Pushing engineering science to the Xtreme

Contents

On the cover: Construction of the massive switchyard for the National Ignition Facility. Once fully deployed, this will be the largest precision "optical bench" ever constructed, measuring 100 by 100 by 100 feet and containing 850 tons of steel. Photo credit: Jacqueline C. McBride.

LLNL Engineering, 925-422-8351
Managed by the University of California for the Department of Energy

Message from the Associate Director

In 1999, Engineering at Lawrence Livermore National Laboratory faced competing priorities to meet critical project milestones, insistent pressures to restructure internally to promote long-term technological growth, and immediate demands to reassign employees as major projects terminated and new ones emerged. This drive for change occurred among an unprecedented level of turmoil within the nuclear weapons design and manufacturing community.

I believe the technical problems were more demanding this year and the environment within which they were accomplished more challenging, pushing us to accomplish more during greater turbulence than any other time in my tenure here. I am pleased to report that we met many key milestones and achieved numerous technological breakthroughs.

In the project support areas, demands presented by our customers shifted significantly over the year. In the lasers area, we continued the detailed designs for the over $1 billion National Ignition Facility (NIF) super laser, paving the way for the procurement of components and structures for what is probably the largest high-tech construction project in the world. This work was undertaken in an environment of significant management and structural changes, with increased reporting requirements from the Department of Energy, starting in the middle of 1999. Despite these changes, our technical progress since 1995 has resulted in a 5000-fold improvement in the performance/cost characteristics of NIF—only a factor of 2 away from where we need to get.

In the defense area, we delivered the first production unit of the refurbished W87 weapon, on schedule, for eventual delivery to the Air Force. Also in the defense area, we developed and implemented a new philosophy for conducting underground materials testing using expendable containment vessels. This allowed us to increase our test throughput rate six-fold and simultaneously reduce cost by a commensurate amount. The first two tests were conducted with a 100 percent data capture rate.

Also in 1999, the Laboratory's major contract on atomic vapor laser isotope separation with USEC Corporation came to an end. Within an intense three-month period, Engineering effectively transitioned its 150 employees working on this project to other Laboratory projects.

We leveraged our competence in microsystems and biosciences to establish a robust technical presence in the field of biological and chemical weapons defense. This year, we saw successful operational tests of several hand-held versions of our analytical instruments. Concurrently, we saw our efforts in information technologies and medical devices pay off significantly, when both these areas grew robustly.

Spiros Dimolitsas

In the operations area, Engineering underwent an important change in its technology investment strategy. In 1998, we consolidated our nine technical thrust areas into five Engineering Technology Centers and restructured these centers to form the Engineering Science and Technology Program, reporting directly to my office. In 1999, we completed the selection of four of the five Directors to lead each of these areas and moved from startup to true enterprise. This 1999 Summary highlights these five Centers.

We continued our facilities restructuring, and worked with the Laboratory to increase our ability to make capital investments and modernize tools in our competency areas. The cumulative financial impact of these changes over the past four years has been a revenue increase of 45 percent and an employee productivity increase of 35 percent.

This report summarizes our 1999 accomplishments. I hope you will find it both interesting and informative. If you want to learn more about our 2000 activities, visit our new Website at *http://www-eng.llnl.gov*.

Engineering Today

Unlike most research and development organizations, the Laboratory must deliver production-ready designs, as well as certify the performance and reliability of the assembled product. Unlike most industry, the Laboratory must pursue R&D that significantly increases the nation's security.

This rare teaming of production engineering expertise and national R&D agenda places the Laboratory as one of the few organizations today that conducts cutting-edge engineering on grand-scale problems, while facing enormous technical risk and undergoing diligent scrutiny of its budget, schedule, and performance.

Just as the Laboratory has a dual mission, Engineering shares a dual responsibility for the Laboratory. We must be prepared to solve short-term engineering problems to meet programmatic milestones. At the same time, we must develop technologies that will ensure the Laboratory's technical competitiveness for the long term.

Xtreme Engineering

On the grand scale, cutting-edge technologies are emerging from our recent ventures into "Xtreme Engineering." Basically, we must integrate and extend technologies concurrently and then push them to their extreme, such as building very large structures but aligning them with extreme precision. As we extend these technologies, we push the boundaries of engineering capabilities at both poles: microscale and ultrascale.

Today, in the ultrascale realm, we are building the National Ignition Facility (NIF), the world's largest laser, which demands an extremely complex operating system with 9000 motors integrated through over 500 computers to control 60,000 points for every laser shot.

On the other pole, we have fabricated the world's smallest surgical tools and the smallest instruments for detecting biological and chemical agents used by antiterrorists.

Throughout this Annual Summary, we highlight some of our recent innovations in the area of Xtreme Engineering. For example, we often use exotic materials to build miniature devices to precise tolerances in extremely clean environments.

Other pioneering ventures

In the last few years, Engineering has significantly pushed the technology in structural mechanics and micro-instrumentation. For example, our DYNA code is widely used both by government and industry to model the behavior of structures under large deformation conditions, such as automobile and aircraft collisions. Today, our codes have expanded to run on the world's most powerful Tflop/s class computer, in the massively parallel, coupled/multi-physics domain.

More recently, in microtechnology, we have designed and fabricated unique microinstruments using lithographic processing. Building on Engineering's pioneering work in precision engineering, we are now able to fabricate complete biomedical and biochemical instruments, often at far less than one-tenth size, with improved performance over current "state-of-the-art" instruments.

These developments are helping us make unique contributions in the fields of proximal and remote sensing related to nonproliferation and counter-proliferation of weapons of mass destruction (such as nuclear, chemical, and biological weapons) and in biotechnology, where we actively support the Laboratory's significant involvement in human genome sequencing.

Partnering with industry

Starting in 1998, the Laboratory further expanded its work with industry, initiating the $250 million extreme ultra-violet lithography (EUVL) project to advance process technology semiconductor fabrication or create the "next-generation computer chip." EUVL represents a unique partnership with industry (Intel, AMD, and Motorola).

A similar pioneering venture, spearheaded by Engineering, teams the Laboratory with GST Communications, Nortel Networks, Sprint, and the Bay Area Rapid Transit system within the National Transparent Optical Network (NTON) Consortium to create the $120 million "next-generation Internet" on the west coast. In 1999, NTON linked Seattle to Portland and San Francisco to San Diego.

Profile of Engineering

Almost one-third of the Laboratory's 7500 full-time employees belong to Engineering. Our current staff of almost 2200—combining expertise in mechanical, nuclear, chemical, electrical, electronics, materials, civil, and other types of engineering—is one of the largest engineering R&D operations in the country. Approximately 1800 staff members are typically assigned or matrixed to work directly with Laboratory programs or other organizations, such as NIF or Defense and Nuclear Technologies.

In 1999, the Laboratory's revenues were nearly $1.35 billion with $4 billion of capital invested in plant and research facilities. Within the Laboratory, Engineering is a $410 million business.

Turning ideas into reality

The Laboratory's primary national security mission—the design, development, and stewardship of weapons—is complemented by programs in energy, environment, biosciences, and the basic sciences.

The mission of Engineering is to turn physics ideas in the programs into reality. In actuality, this means Engineering:

- Designs and often builds production-ready end-deliverables such as, diagnostics for mounting on missile test flights, and portable instruments for detecting chemical and biological agents in the field.

- Designs and is involved in the construction of most of the Laboratory's unique test facilities such as, facilities where weapon materials, weapon parts, or entire weapons are environmentally and/or performance-tested (for example, the over $1 billion NIF "super laser"); or facilities where new manufacturing processes are developed (for example, the $2.2 billion nuclear fuel-production pilot plant for the United States Enrichment Corporation).

- Conducts research in advanced, broad-application technologies that enhance the Laboratory's ability to pursue its mission.

To promote this third Engineering mission—pursuing advanced technologies—in 1998, we restructured Engineering to include five new Engineering Science and Technology Centers, as well as the two existing line organizations: Mechanical Engineering (with five divisions) and

Focus of the National Ignition Facility in 1999 was on completing the over 400,000-square-foot structure, which is similar in size to a large football stadium yet is aligned to micrometer precision.

Electronics Engineering (with three divisions). This center/divisional structure is aligned with Engineering's four functions:

- Product development for defense
- Project engineering for large-scale test facilities
- Technology services for analysis, design, fabrication, and testing
- Research and development

Engineering expertise

Engineering serves as a multidisciplinary organization with expertise in most of the major engineering fields. Its wide-ranging capabilities are a direct outgrowth of the Laboratory's nuclear weapons work and the interdependence of weapons design, computational modeling, engineering, safety, and performance. Engineering personnel simulate engineering systems, improve systems designs, and test performance when built. In addition, Engineering manages numerous large- and small-scale projects requiring complex interactions among many scientific disciplines.

Powerful pulses of green light are generated by this diode-pumped solid-state laser system, one of five 1999 **R&D Magazine** *awards won by LLNL teams featuring Engineering personnel. In this photo, the laser is being aligned so the optical fibers deliver multihundreds of watts of green light.*

Engineering's core competencies focus on:

- Integrated engineering of large-scale, complex, applied physics systems
- Large, complex computation modeling and simulation
- Microscale engineering
- Measurement science at extreme dimensionalities

These four competencies are represented by a number of activity areas, which include:

Systems engineering

- Nuclear and advanced conventional weapons engineering
- Nuclear materials disposition
- Laser systems engineering
- Isotope separator engineering
- Safety-critical control systems
- Accelerator and particle detector systems engineering
- Field engineering
- Security control systems
- Adaptive optics
- Electronic commerce and concurrent engineering systems

Engineering modeling and analysis

- Structural, thermal, and fluid system analysis and design
- Nonlinear systems modeling
- Bio/human system modeling
- Accelerator and microwave electronics analysis and design
- Antenna modeling
- Nuclear and electromagnetic radiation effects
- Integrated photonics
- Information systems vulnerability analysis and operations
- Transportation vehicles, systems, and infrastructure
- Natural hazards assessment and mitigation

Microsystems and precision manufacturing

- Precision, brittle material fabrication
- High-precision optics
- High precision diagnostic instruments
- Miniaturized, integrated analytical bio/chemical systems
- Medical micro-instruments and micro-tools
- Genome sequencing instrumentation
- Optoelectronic communication devices

Measurement and testing

- Real-time data acquisition and processing
- Transient diagnostics
- Remote characterization and detection systems
- Ultra low-power, precision proximity radars
- Adaptive sensors and networks
- Nondestructive evaluation
- Accelerated materials aging
- Biomedical imaging
- Geologic signal processing and analysis
- Sub-surface (including underground) imaging
- Environmental monitoring and characterization

Engineering facilities

Engineering manages 28 facilities at the main 1-mile-square site in Livermore, California, about 45 minutes east of San Francisco. These total 770,000 gross square feet, with 70 percent dedicated to working engineering laboratories, shops, and computer equipment and storage space, and the remaining devoted to office space. In addition, Engineering operates 34 buildings and magazines at Site 300, a 45-mile-square test site about 30 minutes away.

Engineering facilities include a wide array of capabilities to support our Laboratory programs. In the future, focus will be on strategic investment to revitalize older structures for continuing service.

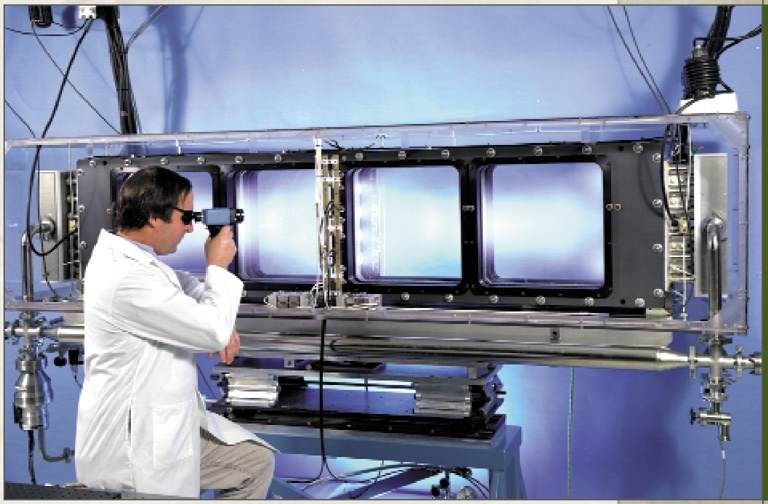
Special capabilities

Within Engineering's 28 facilities, we have developed special capabilities that advance our technical expertise and boost leading-edge results. The following is a sampling of the highlights; for more detail and photographs, visit our Website at *http://www-eng.llnl.gov*.

Our new microfabrication building houses 3500 square feet of Class 10-1000 clean rooms for micromachining, silicon microelectronics, III-V semiconductor optoelectronics, and guided-wave photonics. Other labs provide material characterization and device-testing capabilities, microscopic inspection, packaging, and electrical and optical testing of devices.

Our Large-Optics Diamond-Turning Machine (LODTM) is one of the largest diamond-turning machines in existence with capacity for parts up to 64 inches in diameter, 20 inches tall, and weighing up to 3,000 pounds. The contouring accuracy of the LODTM is 1 microinch root mean squared. The machine, which can create mirror surface finishes, is used for both machining and inspection operations.

The unique connectivity at the Laboratory between electromagnetic modeling, design, construction, experiments, systems analysis, and field work allows Engineering to work in many leading areas in high power systems. Our abilities in plasma and high power systems allow us to design, construct, and test total systems including the necessary support circuits, subsystems, and software. Several facilities support this work such as, an anechoic chamber and a large-scale test antenna.



Each plasma electrode pockels cell in the National Ignition Facility (NIF) acts as a giant light switch for four beams. When used by NIF, they will be uniquely arranged vertically in a single replaceable unit, called a plasma electrode pockels cell, which enables NIF's multipass architecture.

The New Technologies Engineering Division's high pressure lab is one of the most complete high-pressure design, fabrication, and testing facilities in the world.

In addition, the Division's Rapid Prototype Facility consists of three interrelated facilities:

- Central Drafting, which is equipped with computer-automated design and drafting (CADD) systems and offers a wide variety of electro-mechanical drafting services.

- Electronic Fabrication/Packaging, which works closely with customers to design and fabricate chassis, subassemblies, cable assemblies, encapsulation, fiber optic termination, various mechanical subassemblies, and to produce complete documentation packages for prototype and pre-production units.

- Printed Circuit Load/Surface Mount Technology/ Through-Hole Technology facility, which offers state-of-the-art surface mount and through-hole technologies to satisfy a variety of customer needs. Fabrication specialists at this facility expertly assemble microscopic components on printed circuit boards to high tolerances using infrared reflow and delicate hand-soldering techniques.

The Manufacturing and Materials Engineering Division provides expertise in manufacturing technology, precision engineering, materials engineering, and measurement systems. These capabilities are supported by extensive and up-to-date facilities, laboratories, and equipment.

The National Ignition Facility demands a special ultraclean maintenance and assembly. In this photo of the specially designed assembly cart, a technician is inserting a cassette into a frame assembly unit in the Amplab, the multimillion-dollar facility for testing the main amplifiers that was jointly developed by LLNL and the French.

Technical Accomplishments

NIF technical progress escalates 5000-fold; rebaselining proceeds

The National Ignition Facility (NIF), the largest and most powerful solid-state laser ever built, will be a key test facility for verifying the health and viability of the nuclear weapons stockpile without physically testing the weapons themselves. The 10-year-long, billion-dollar construction project will also achieve nuclear fusion, the energy source of the sun and other stars.

To achieve these massive feats is an exercise in Xtreme Engineering, that is, the integration of multiple technologies driven to their extremes. In the case of the NIF, 1000-foot-high structures must be aligned to micrometer precision, 5000 networked computers must work in sync to control the precise alignment of the target and the incoming 192 laser beams, and 2700 clean-room assemblies must be dirt-free down to the level of 100 particles or less per cubic meter.

Groundbreaking on the NIF occurred in May 1997, and by the end of 1999, the $250 million conventional facility (building structure) was 85 percent complete, meeting its fabrication and cost milestones. When completed, the giant laser will offer a 10,000-fold improvement in technology through pioneering science and engineering. At the end of 1999, just two years since groundbreaking, we are only a factor of 2 away from achieving all the technical breakthroughs and have already reached the 5000-fold marker. Specific areas of improvement have been the production of glass 3 times cleaner and 10 times cheaper, growth of crystals in one week rather than one year, fabrication of pockels cells that are 10 times larger, and a four-fold improvement in optical damage thresholds.

During 1999, one of the highest visibility activities for the NIF was the completion and installation of the target chamber into the target bay. Following in this engineering milestone was the final vacuum leak testing of the target chamber and application of the external "gunnite" shielding. The chamber now sits ready in the target bay. Unlike the other laser system components, the target chamber—because of its huge size and weight—had to be installed before the building was completed and the roof installed. Therefore, we consider it a major pacing item.

Of special technical interest is this year's demonstration of the largest example of pockels-cell technology. We demonstrated that the full-scale NIF plasma electrode pockels cell (PEPC), an optoelectronic switching system for passing light back and forth through an amplifier, will work in NIF and other machines of this magnitude. The geometric packaging of the PEPC is difficult because the NIF laser beams are clustered so closely together.

In 1998, we built the structure to house the National Ignition Facility target chamber; in 1999, we installed the 33-foot-diameter chamber. This task needed to be completed before the roof was installed because of the chamber's massive size and weight. Within this chamber, 700 terawatts of laser power will be deposited, which equals seven times the output of all United States power plants.

The refurbished W87 simulated warhead launched at Vandenberg Air Force Base met all military milestones.

Therefore, we had to devise a very compact and novel, square pockels-cell configuration.

At the same time, we have had to cope with budgetary and schedule problems, which came to light this fall. These issues have caused increased oversight, reorganization of personnel, and intensive cost and schedule rebaselining of the NIF engineering, procurement, installation, and commissioning activities. As part of the reorganization, we have brought in more Engineering staff, and there is more emphasis on rigorous application of engineering processes to ensure successful project completion.

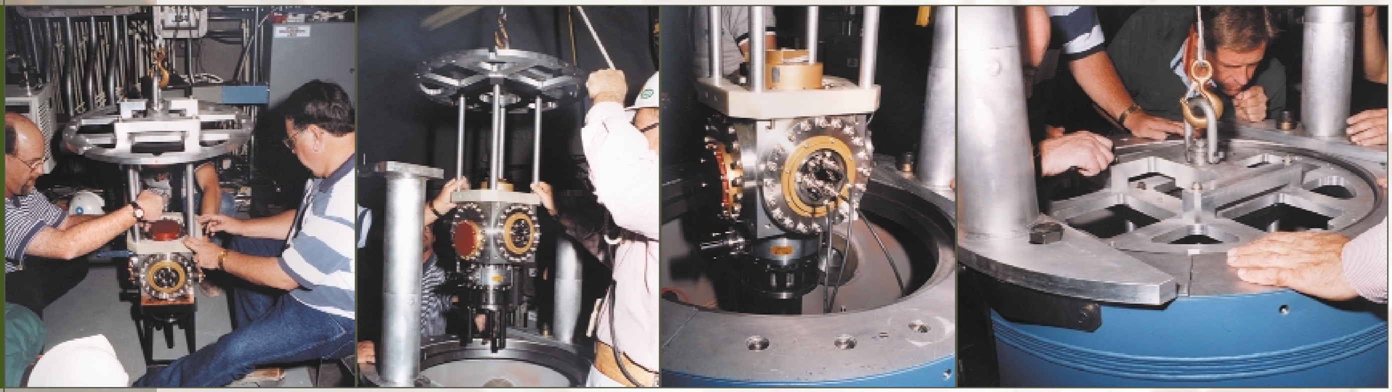
Production W87 warhead delivered to Air Force

Lawrence Livermore maintains four systems in the active and reserve stockpile of nuclear weapons for the United States. Of these, the W87 is the most modern design of a weapons system, yet one that continues to demand monitoring and refurbishment as components change throughout the lifetime of the weapon.

Beginning in 1994, the Laboratory has worked with the Air Force to meet their need for a more durable W87/Mk21 warhead and reentry vehicle. In the process, we have enhanced the structural integrity of the W87 warhead, as well as ensured its longevity for another 30 years.

Refurbishment is a much more difficult task today because we can no longer perform a fully integrated (that is, nuclear) test of the modified warhead at the Nevada Test Site. In addition, we no longer have either the original manufacturing plants in operation or the same production processes in use.

As part of this upgrade requested by the Air Force, in February 1999, the first production unit of the refurbished



This sequence illustrates instrumentation positioned into disposable steel vessels for the Oboe explosives experiment. Because of their novel design, the vessels save money and promote more frequent experimentation.

warhead was assembled at the Pantex plant in Amarillo, Texas, with Laboratory personnel performing engineering evaluations during the assembly process. The refurbished W87 maintains the Air Force's military requirements. In June, the initial operational quantity of warheads, including this first production unit, was delivered to the Air Force.

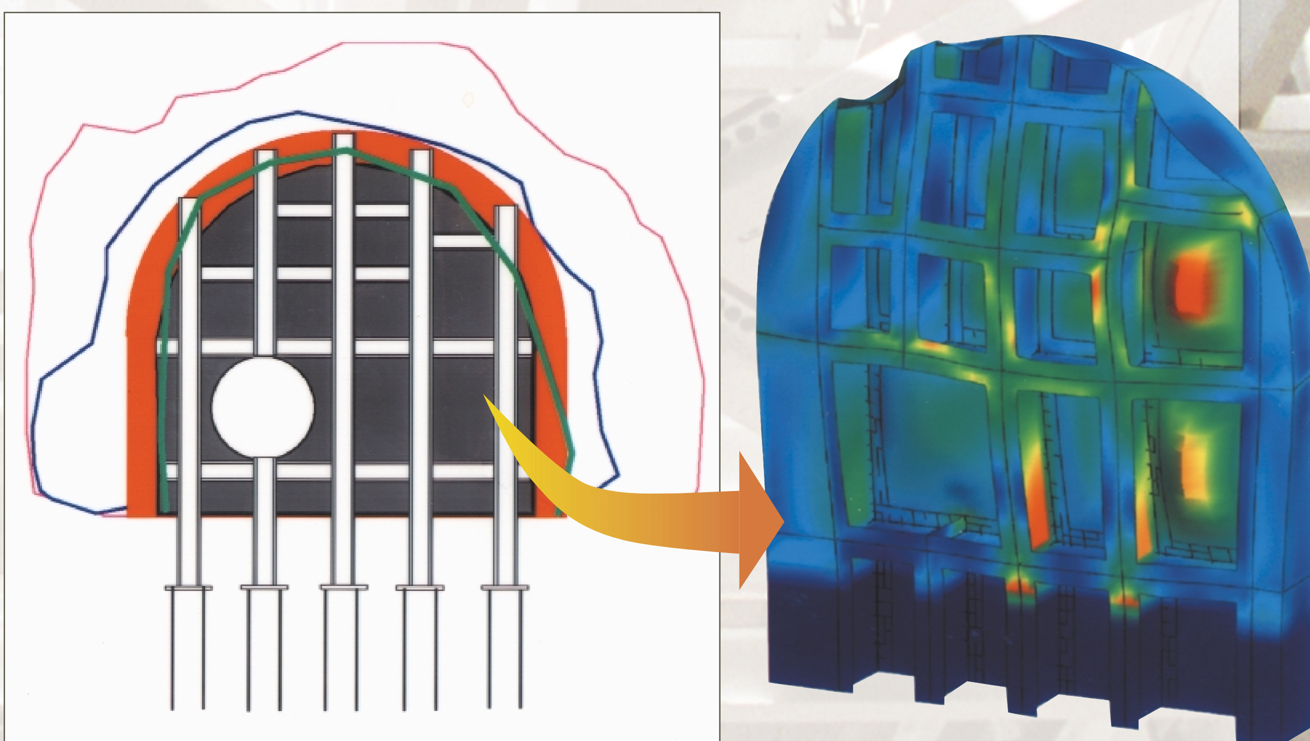
Oboe team cuts costs with unique vessels

The Oboe subcritical experiments investigate the dynamics of plutonium when shocked by high explosives. In late 1999, the Oboe team conducted the first two Oboe experiments at the underground complex at the Nevada Test Site, and each successfully captured 100 percent of the data.

This year, engineering personnel originated the idea of conducting the experiments in disposable steel vessels (measuring 3 feet in diameter and 4 feet tall) to significantly reduce project costs and experiment turnaround time. The new experimental vessel contains the shock, pressure, and debris generated during the test. Holographic imaging, x-ray imaging, Fabry-Perot velocimetry, and piezo pins are used as the diagnostic instruments for each test.

With the new vessels, up to a dozen Oboe experiments can be conducted in a single zero room, eliminating the need to mine a new room and equip it for each test. The associated diagnostic rooms are also left intact for the next test, which saves the time and costs previously spent moving the rooms and their diagnostics. The engineering team estimates they will now be able to perform up to 10 tests per year with these vessels in contrast to the one to two performed annually before.

An enormous technical challenge to the engineering team is the difficult "field" environment for testing. All Oboe tests are conducted 1000 feet below the ground.



Employing the multiuse DYNA3D code developed at Livermore for nonlinear structural analysis, engineers have been able to develop a shell model of the blast barrier to the Oboe "zero room."

Therefore, the comprehensive clean room optical laboratories need to be set up and then moved deep under the desert floor, while the incredible cleanliness required for such tests must be maintained in a hostile environment. Additional tests in the Oboe series, the successor to the Clarinet series, are planned for 2000.

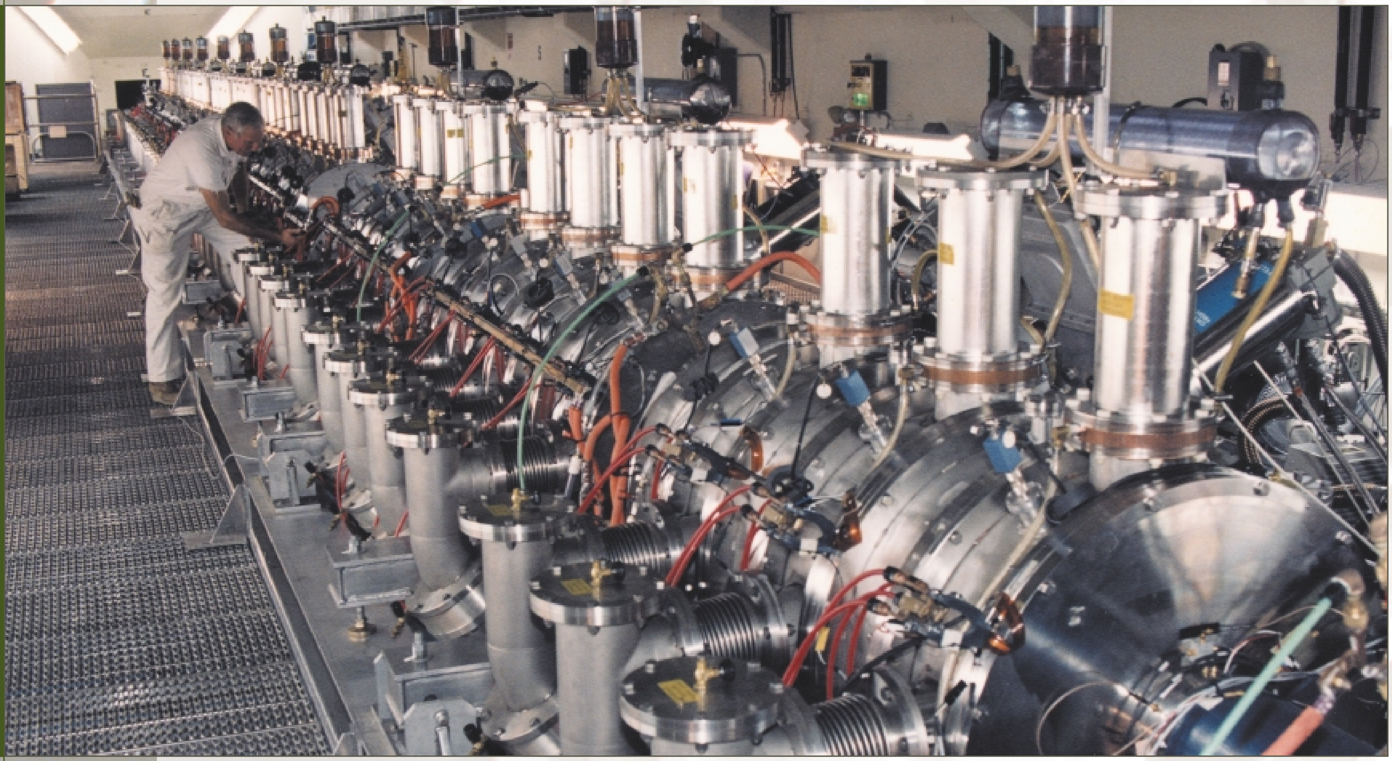
Flash X-Ray upgrade creates double photos

In 1999, Engineering upgraded the Flash X-Ray (FXR) Accelerator to produce two x-ray pulses for observing explosion characteristics of mock weapon subassemblies more precisely. The FXR, originally commissioned in 1982 with only single-pulse radiography, is located at Site 300 and is being integrated into the Contained Firing Facility there.

Two types of testing verify the behavior and integrity of the nuclear stockpile. Tests related to the primary analyze the behavior and geometry of the actual explosive test, often using an accelerator to capture one or more x-ray snapshots of the explosion or imploding unit. Tests related to the secondary, such as the use of the NIF, evaluate the physics of the materials under high-energy and high-density conditions.

The new FXR Double Pulse upgrade now delivers the unique capability to take two, time-resolved, x-ray photos of a dynamic test of a simulated primary, often called a hydrotest because the explosion liquifies the components. The FXR upgrade accomplishes this in a very cost-effective manner by triggering alternate accelerator cells. The odd-numbered cells accelerate the first pulse, the even cells, the second.

During the FXR photography process, x-rays are generated by two electron pulses, which can be adjusted to occur any time within 1.5 to 5 microseconds—that is, any interval conducive to test requirements. Each pulse produces a 2.5 to 3 millimeter spot size with an x-ray dose of 60 to 80 roentgen at 1 meter from the target. Now scientists and engineers studying radiographs can more clearly see the unusual movement of materials that occurs during any high-powered implosion.



The Flash X-Ray Accelerator can now produce two x-ray photographs of explosive tests, allowing scientists and engineers a much more accurate analysis of the event.

A team of eight mechanical and electrical engineers has worked on the FXR upgrade since 1996. The technical challenge over the past three years was to reconfigure the pulsed power and trigger systems, and improve magnetic guidance to transport two nearly identical electron beams through the accelerator. The upgrade, a major Department of Energy milestone, was completed on time, within budget, and met operational performance specifications. Elements of the double-pulse upgrade will also improve single-pulse performance.

Handheld analyzer performs biodetection in real time

A new, portable polymerase-chain-reaction (PCR) detector enables first-responders to detect and identify biological agents in real time at the site of a biological incident, such as the deliberate release of anthrax. This capability provides fast and appropriate response to minimize exposure and, ultimately, fatalities.

HANAA, which stands for the Handheld Advanced Nucleic Acid Analyzer, is the culmination of seven years of technology development, beginning with Laboratory internal funding and later earning Department of Defense as well as other funding. The highly portable instrument measures 4 by 10 by 2 inches, weighs 2 pounds (6 pounds with battery pack), and promises real-time detection in the field. The tool incorporates an embedded microprocessor, three microcontrollers, seven custom electronics assemblies, a custom keypad, and a small graphics display.

HANAA performed successfully in two field tests in 1999, the first onsite at the Laboratory and the second at the Nevada Test Site. Field tests compared favorably with benchmark lab data. In comparison to other PCR instruments, HANAA is very fast, much smaller, and easier to take into the field. The first beta test will be used to monitor water supplies in real-time in remote areas. Also, in contrast to similar detection instruments, HANAA shows a faster processing time, detection rate, and nearly zero false positives.

HANAA incorporates a new, compact, optical-detection system and a patented micro-fabricated silicon thermal cycler. According to the Engineering personnel who developed this newest detector, the most challenging part of the project was building a complex hardware/software system from the ground up that had the look, feel, and functionality of an off-the-shelf product.

HANAA provides real-time detection of biological catastrophes.

While the applications of HANAA to the defense world are immediate, there are also non-defense uses, for example, detection of pathogens in food and drinking water. Also, HANAA could be used to rapidly identify the source of infectious disease outbreaks in remote parts of the world.

NOVA chamber disassembled; sent to France

Fourteen years after it was built, the NOVA target chamber has been disassembled by Engineering for use by the French in their new LIL laser, a prototype laser similar to the NIF. NOVA—built to perform weapons physics, ignition physics, and astrophysics research—was the most powerful solid-state laser in the world for over a decade, successfully producing up to 120 kilojoules of infrared energy to target its 10 beams. During its history, NOVA produced 120 terawatts of power in 100 picoseconds and delivered over 13,000 experimental shots. Measuring in today's dollars, NOVA would be a $350 million test facility, but perhaps its greatest value was as a catalyst to the precision optics industry.

Using a two-shift crew, work began on disassembling equipment surrounding the 16-foot-diameter, 36,000-pound chamber in June and was completed in

The NOVA laser target chamber is lowered into the "beluga" airbus for shipment to France.

November. Because of the high dollar value of the chamber and the extreme fragility of the optics and potassium diphosphate crystals attached to the chamber, the disassembly process was formally reviewed several times during the year.

Most of the lifting fixtures and lift procedures were reengineered to take into account much more stringent safety measures than existed in 1986 when NOVA was first assembled. Some chamber system components were salvaged to be used at other Department of Energy facilities, and some will be reused on the NIF. The chamber also needed to be decontaminated of low-level tritium to meet standards required for international transport. Decontaminating the chamber meant physically sanding the entire interior in full suits and respirators.

A chamber transportation stand was designed by the French for their Airbus cargo plane but manufactured in the United States with oversight by Engineering personnel concurrently with the NOVA disassembly. Then, each of the three sections of the chamber was removed from the NOVA target bay and reassembled on the transportation stand at a 90 degree rotation (for fitting within the aircraft). The reassembled NOVA chamber was transported by truck to a local airport, about 50 miles away, in the middle of the night. It was loaded onto the Airbus plane, which the French call "beluga" because it resembles a whale, and arrived safely at its destination in Bordeaux, France, on December 12.

Nuclear scanner technology transferred to industriy for radioactive cleanup

Across the nation sit 600,000 barrels of radioactive waste. The contents are often unknown because many of the 55-gallon barrels or metal drums were sealed by scientists decades ago. A new twin technology, combining waste inspection tomography with nondestructive assay (WIT-NDA), can peer into the drums, and without opening them, safely determine the waste matrix or mix, including the amount of radiation inside.

Specifically, gamma rays are beamed through the drum into detectors on the other side, and dense items, such as lead, cement, and radioactive forms of plutonium, stop that beam from coming through the drum. Gamma rays emitted from the waste matrix (for example, plutonium) are also determined, using the external detectors while the external sources are shuttered. Combining both measurements results in a very accurate, nondestructive radioactive assay.

The process began in the early nineties using juice cans and an Engineering technology development investment. The small-scale work then earned a Director's Initiative from the Laboratory Directed Research and Development funding and then additional investment from the Department of Energy from Environmental Management. In the mid-nineties, the Laboratory part-

Sealed metal drums of unidentified waste, possibly radioactive, can now be analyzed onsite and without hazard to the operator.

nered with Bio-Imaging Research of Illinois under a Department of Energy program to build the prototype inspection devices and perform testing. However, the WIT-NDA process, while very accurate, was time-consuming. According to the engineers, it would have taken many decades to characterize the current "stock" of waste drums.

In 1999, Engineering developed a new way to speed up the process using a new NDA instrument with six detectors. What used to take one or two days was now reduced to about one hour per drum, which is estimated to be more than a 20-fold savings. In mid-1999, the WIT-NDA technology was officially transferred to Bio-Imaging Research (BIR) for commercialization. BIR currently has a contract with Rocky Flats, Colorado, to use the WIT-NDA system to assay the waste destined for the Waste Isolation Pilot Plant located in Carlsbad, New Mexico.

New hazardous gas detection system tested

This summer two remote chemical-gas-detection systems were successfully deployed and tested at the state-of-the-art toxic-gas discharge facility at the Nevada Test Site. The first test featured a novel laser-based detection system, called Chemical Analysis by Laser Interrogation of Proliferants (CALIOPE), aboard the Air Force ARGUS KC-135 aircraft. The second experiment used the Hyperspectral InfraRed Imaging Spectrometer (HIRIS) system aboard the NASA WB-57 aircraft. CALIOPE's active laser technology offers superior detection sensitivity, while the passive imaging system of HIRIS provides simultaneous spatial, spectral, and temporal information.

CALIOPE, which flies at 25,000 feet, uses a frequency-agile, tunable, infrared laser within the aircraft to "interrogate" or probe the plume coming from a plant capable of building weapons of mass destruction. The laser is fired through the plume and reflected back from the ground to produce a signal that indicates the composition of the plume, and, thus, the likelihood that weapons are being manufactured inside the building.

The HIRIS-57 is a high-altitude version of last year's testing aboard the Citation aircraft. This year's flight analyzed the reliability of the performance of the HIRIS instrument in extreme environmental conditions at 60,000 feet.

EUVL remains top choice for smaller computer chip

In 1999, the Extreme Ultraviolet (EUVL) Technology project—a partnership between the Laboratory, Sandia,

A more accurate deposition system is now used to produce precise, uniform, highly reflective masks. In 1999, the Extreme Ultraviolet Technology project made major progress in producing virtually defect-free masks.

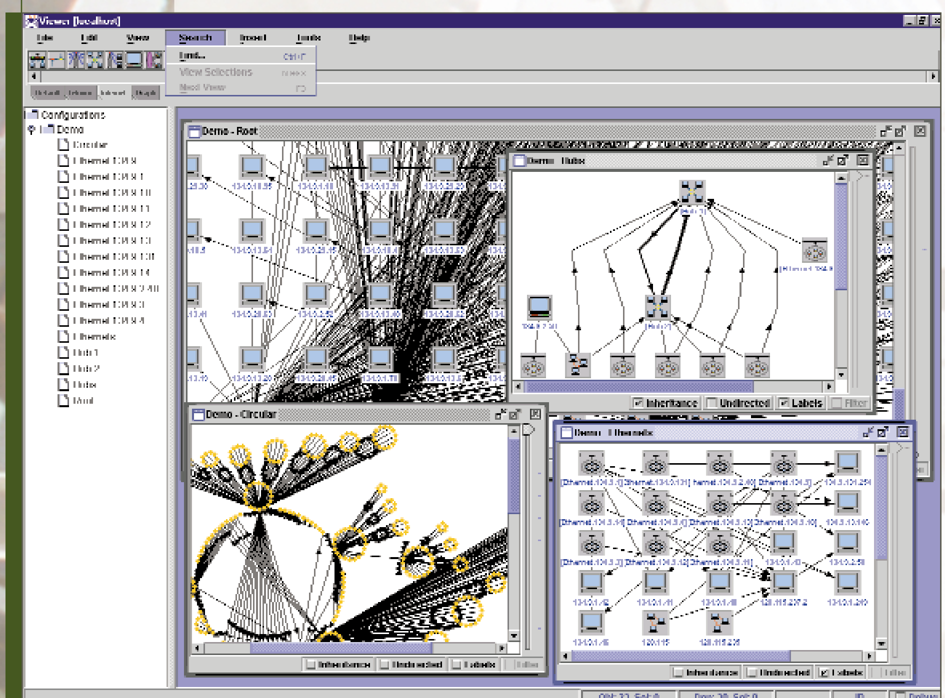
and Lawrence Berkeley national laboratories, and funded by a semiconductor industry consortium (Intel, Motorola, and AMD)—continued be the leader in technologies competing to print the next generation of the world's smallest computer chip. EUVL uses optical technologies with a very high level of precision and cleanliness to print circuits on computer chips.

Basically, the team is attempting to pattern lines on silicon chips as small as 30 nanometers wide; the current standard is 180 nanometers (which cannot be seen with a standard microscope). Standards for cleanliness are the highest in the world because of the miniaturization of the process.

In lithography, the master image for the circuit is placed on a mask, which is used as the printing master. EUVL engineers have pioneered a reflective rather than transmissive mask. In 1999, with this mirror-like surface, the EUVL team was able to demonstrate that they could achieve fewer than three 90-nanometer defects per mask. This represents a performance improvement greater than a factor of 10, compared to the previous year, and a critical milestone in commercializing EUVL.

Additional technological breakthroughs have made advances in EUVL possible. Laboratory scientists and engineers won an R&D 100 Award in 1998 for their work in building an interferometer capable of characterizing the shape of optical elements with sub-nanometer precision. Also, in aligning the precision optics for EUVL, they successfully integrated into complete systems new methods to position and move mechanical structures with 20-nanometer precision. In 1999, the project team won another R&D 100 Award for developing a method to uniformly coat the curved optics with atomic-level precision required to maintain the precision and high resolution of the optical system.

Cybersecurity computer tools thwart international attacks



Using cybersecurity tools developed by the Information Operations Warfare and Assurance Center, massive computer networks can be analyzed and reduced to a manageable size so that vulnerabilities can be identified and corrected.

As our nation grows more and more dependent on global communications and computing, we become more vulnerable to computer attacks. At the same time, these attacks are increasing and becoming more sophisticated. The Information Operations Warfare and Assurance Center (IOWAC) was created to address this vulnerability by providing science and technology solutions to prevent, detect, and respond to security threats. It is a collaborative effort between Engineering, Computation, and the Nonproliferation, Arms Control, and International Security organizations at the Laboratory.

Launched in 1998, IOWAC focuses on developing and building defensive cybersecurity tools. This year, the center has grown in number of employees, its cross-functionality between technical disciplines, sponsors, revenues, and scope.

For example, the Computer Incident Advisory Capability (CIAC) effort, which is responsible for the entire Department of Energy complex, has tripled in size and budget. It was through their efforts that the

Department of Energy was able to significantly limit the spread of the Melissa virus. CIAC's weekend response to the new virus was crucial and saved millions of dollars. The center has also increased significantly the number of tools they can use to thwart attacks.

Today, IOWAC is working to solve information protection problems:

- How are our domestic information systems vulnerable to attack?
- If attacked, what would be the consequences?
- What actions can be reasonably taken to successfully protect these systems?

NTON builds two more West Coast links on the "SuperNet"

The National Transparent Optical Network (NTON) Consortium is a partnership between the Laboratory, Nortel Networks, GST Communications, Sprint, and, now in 1999, the Bay Area Rapid Transit system. In their quest to build the West Coast leg of the next-generation Internet, called "SuperNet," NTON has linked San Francisco to Los Angeles in April and Portland to Seattle in October. This linkage involves 10 billion bits per second data rates using the first pair of wavelengths (of eight available pairs) on one fiber optic strand, which will eventually span the West Coast.

Using these two new links and capacity borrowed from the Electric Lightwave company, NTON was able to nearly quadruple the amount of data that could be demonstrated at the annual premier event of the computing world, the Supercomputing and Communications Conference, in November. Through this new high-bandwidth, high-profile connectivity, NTON linked the West Coast sites of Sandia, Lawrence Berkeley, Stanford Linear Accelerator, NASA-Ames, California Institute of Technology, Jet Propulsion Laboratory, the University of Washington, and Microsoft to powerful computing demonstrations on the exhibition floor in Portland. The remaining agency and research networks linked major research sites throughout the country to and through the national transparent optical network to the conference as well.

This dime-sized semiconductor optical amplifier reduces crosstalk by a factor of 10,000 and noise in fiberoptic communications. SuperNet, which will link Seattle to San Diego, is made possible by optical devices such as this amplifier.

Potassium diphosphate (KDP) crystals, the largest grown in the world, can be finished to exacting optical specifications in the National Ignition Facility. This photograph shows a KDP doubler in the optics processing laboratory.

In 2000, NTON plans to link Portland to San Francisco and Los Angeles to San Diego. Within Engineering, this new high-bandwidth capability built by NTON has leveraged emerging Laboratory programs in global climate modeling, cancer radiation analysis, and embryology research. The goal for Engineering is to be a major player in the future of communications and networking R&D. Powerful yet secure connectivity to its peer R&D communities is central to achieving that goal.

Peacekeeper testing for the Air Force pioneers new instrumentation

In their annual testing of the Peacekeeper intercontinental ballistic missile, Engineering merged new instrumentation with the high-fidelity testing of a simulated warhead using representational components. The goal of the March testing, performed in concert with Sandia at the Kwajalein Missile Range in the Marshall Islands, was to verify accuracy of the missile and response of the warhead to the flight environments.

Tracking and monitoring systems, located off-board, determined if the simulated warhead functioned properly at the target site. These systems were developed by the defense divisions within Engineering.

The new instrumentation consists of accelerometers, acoustic sensors, and similar diagnostics. These were attached to the FTU-15 reentry vehicle. The instrumentation takes advantage of new developments in microelectronics, sensors, and system integration while maintaining warhead and flight test fidelity. The resulting flight data has significantly furthered our understanding of warhead response.

The Peacekeeper missile is launched from Vandenberg Air Force Base, featuring new instrumentation to improve data reporting.

Business Accomplishments

In 1999, we continued to map our activities to our strategic plan developed three years ago and centered on three high-level, long-term goals for Engineering:

- Deliver on all project milestones—safely.
- Become vital to the Laboratory by developing the breakthrough technologies upon which the next multimillion-dollar programs will be based, and develop the leadership team to realize and assume key responsibilities for such programs.
- Significantly increase Engineering's level of recognition within the national engineering community so we can continue to attract and retain exceptional people.

The following five major business accomplishments for 1999 reflect our three goals by centering on our key roles in the milestones of the Laboratory's major programs, as well as the immediate needs within our own internal structure and organization.

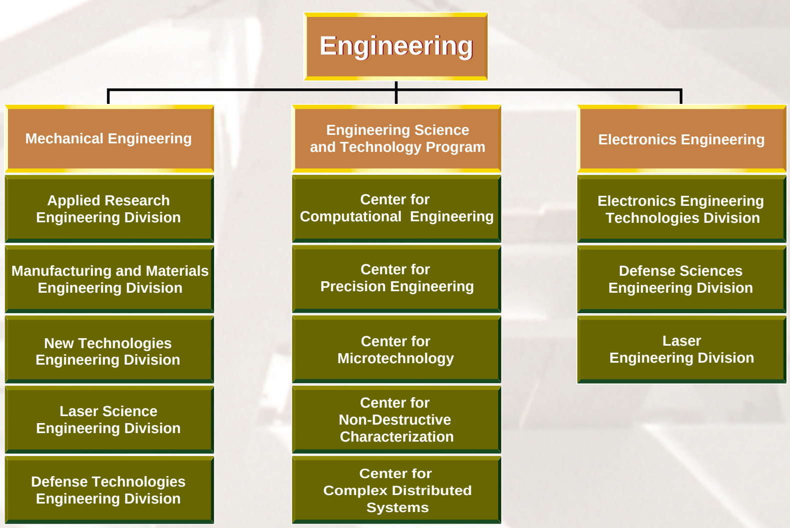
Meeting major defense milestones

First, Engineering met many critical Laboratory program milestones. Most notably in February 1999, we delivered the first production unit of the refurbished W87 weapon, on schedule, for eventual use by the Air Force. This delivery is the result of approximately six years of a life-extension program for this weapon system. Also in the defense area, we developed and implemented a new philosophy for conducting underground materials testing using expendable containment vessels. In the OBOE series of tests, we were able to increase our test throughput rate sixfold and simultaneously reduce cost by a commensurate amount. The first two tests, which were conducted in early and late fall, allowed a 100 percent data capture rate.

In the lasers area, we continued the detailed designs for the over $1 billion National Ignition Facility (NIF) super laser, paving the way for the procurement of components and structures for what is probably the largest high-tech construction project in the world. This work was undertaken within an environment of increased oversight and resulting significant management and structural changes that took place in the middle of 1999. Despite these new directions, our technical progress since 1995 in the key risk areas of glass production, optical switching, three omega damage, and crystal growth resulted in a 5,000-fold improvement in the performance/cost characteristics. This is only a factor of 2 from reaching the 10,000-fold improvement needed to achieve ignition at an acceptable cost.

Making personnel adjustments

Meeting these and many other milestones required us to hire or move a significant number of employees across business activities, 500 in total. During this process, we experienced the tightest labor market in the Bay Area over the last 25 years. The primary driver behind the significantly increased number of moves was the sudden termination of the Laboratory's Atomic Vapor Laser Isotope Separation program. In just a few weeks, we had to find new positions for approximately 150 Engineering personnel and did.



Reducing costs; starting new initiatives

Second, Engineering continued to operate in a cost-aggressive manner. In fiscal year 1999, our revenue (as reflected in our cumulative payroll, equipment purchases, and outsourced services) was equal to $407 million, an increase of 45 percent over the last four-year period. Simultaneously, our operating costs decreased from 18 percent of revenue to 9 percent, which, when combined with our workforce restructuring in 1996, has led to a productivity growth of 36 percent over the four years.

In addition to overhead/operating cost reductions, Engineering positioned itself to sustain the funding available for core competency development while decreasing the cost to its customers by 10 percent. This objective was largely achieved through a combination of organizational restructurings, divestment from facilities, and reduction in other capabilities no longer strongly coupled with the Laboratory's future mission. At the same time, we invested $3 million for capital equipment and developed an investment strategy for a continuing $3 million influx of funding for capital equipment in fiscal year 2000, allowing us to start two major initiatives: one on a communications and networking laboratory and another on mesoscale manufacturing.

Restructuring boosts technology investments

Third, Engineering underwent a significant restructuring of its technical investments operations. Starting in fiscal year 1998, its nine thrust areas were consolidated into five Engineering Technology Centers exploring future innovations in computational engineering, microtechnology, precision engineering, nondestructive characterization, and complex distributed systems. These five Centers, which collectively form the new Engineering Science and Technology program, now report to the Office of the Associate Director, rather than being embedded in one of the eight engineering divisions as the thrust areas were. In 1999, we selected new leadership for four of the five areas.

As part of this reorganization, the Centers have been given responsibility for the vitality and growth of the core technology each represents. These new units are specifically designed to bring together the best of both mechanical and electronics disciplines, creating a synergy that most organizations cannot. The expectations are that the Centers will produce breakthrough technology that solves compelling Laboratory problems, that puts Engineering on the national map, and that fundamentally changes the way we go about doing our business. A separate document, *Engineering Research, Development, and Technology,* provides a technical summary of our work in the Centers and other key areas, that is, how we spent our money in fiscal year 1999.

Improving safety and security

In addition to meeting our prescribed milestones in 1999, we devoted considerable time and energy to significant new initiatives to improve Engineering's safety and security, particularly cybersecurity. This work was required in the context of increased external demands by the Department of Energy for the Laboratory as a whole to improve in these two areas.

In particular, Engineering amplified its effort to improve safety throughout the organization, in preparation for a full-fledged implementation of an Integrated Safety Management (ISM) system in fiscal year 1999 throughout the Laboratory. This increased emphasis on safety has been accomplished through focused management attention (especially monthly safety walkthrough programs by senior management) and commitment to safe and effective operations, an expansion of Engineering's grassroots safety program, an ISM half-day training program for all Engineering personnel, a restart of the Engineering safety newsletter, and other safety-oriented programs.

Overall, our safety record has improved significantly. Specifically, our cost index (a metric used to measure the combined frequency and severity of injuries) improved from 15 in fiscal year 1998 to 7 in late fiscal year 1999. This represents a 50 percent reduction in necessary costs caused by safety-related incidents. Coupled with reductions of more than 60 percent over the prior two years, we can clearly take pride in having improved our safety record dramatically. In fiscal year 2000, we will continue to focus on safety as we strive to attain an injury-free workplace.

New Ventures: Technology Centers

Tougher than rocket science

For most engineers, progress is built by small, step-by-step improvements. But for a few engineers, those pioneering the frontiers in technology, 100-fold improvements are part of doing business. That's what we call "Engineering at the Edge."

Designing a device to detect biological and chemical agents in the field may demand a 100-fold improvement in size and speed. Scrutinizing the radioactive contents of discarded waste drums safely and remotely may require a 100-fold improvement in detection and analysis methods.

The bio/chem agent detector and waste drum analyzer are two projects advanced this year by Engineering's five Science and Technology Centers. Our Technology Centers were established in 1998, created to grow new technologies for the benefit of Engineering and the Laboratory as a whole. Our new Centers are positioned primarily not to solve today's problems but to pioneer innovative R&D work for emerging problems, like a smaller computer chip, safer suspension bridges, or more accurate targets for the National Ignition Facility.

Engineering must work to sustain the Laboratory's competitive edge; we must create products or systems that are technically one-of-a-kind. It is an enormous agenda for five new Centers—probably tougher than rocket science. But with a comprehensive multidisciplinary approach—for which the Laboratory is famous—we expect to wow the engineering community.

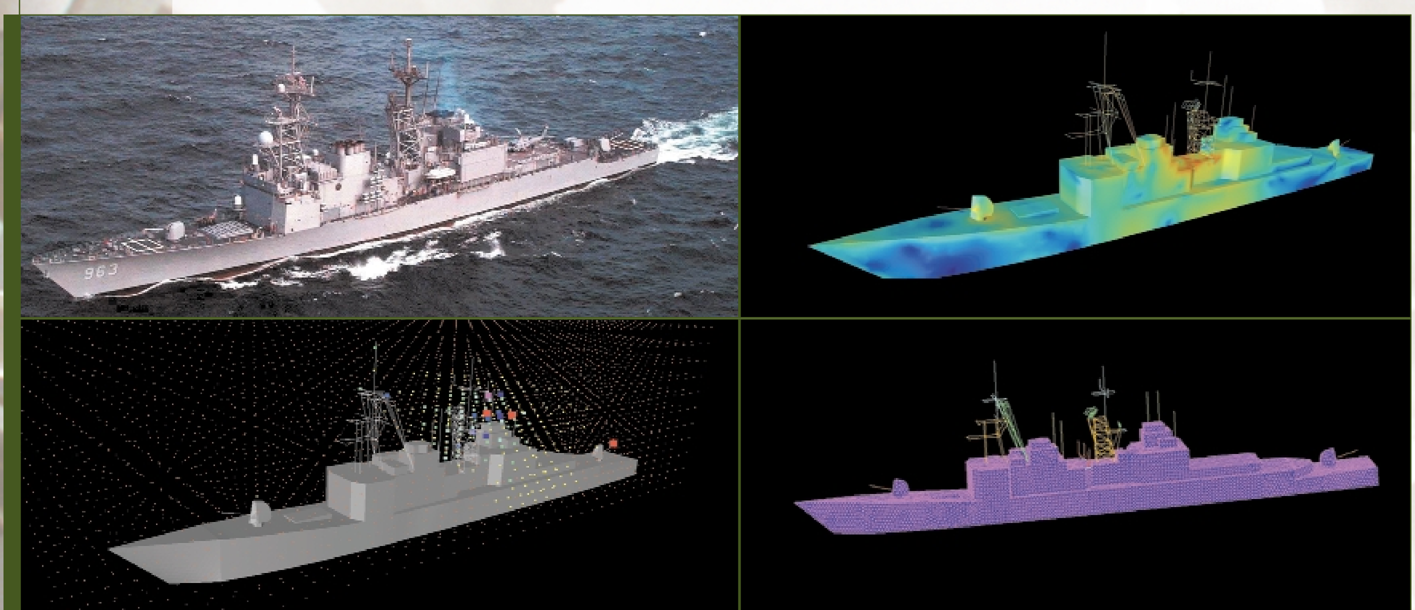
Advanced diagnostics, developed by Engineering, are used to verify performance of reentry vehicles at the Kwajalein Missile Range in the Marshall Islands.

Center for Computational Engineering

Imagine learning a new language but the vocabulary changes and grows every year. That is the scenario faced by today's software code developers where new computer languages or new versions of older languages emerge every year.

Software engineering, the newest member in the family of engineering disciplines, is built on programming languages and software design abstractions that did not even exist at the time of the Manhattan Project. Yet this new field accounts for one of the most vibrant areas of current high tech research today. The workhorse legacy FORTRAN language is only about four decades old (with its most useful variants less than half that), C++ has been around for only about a decade, Java, half that, and Java3D for only about a year. Today at the Center for Computational Engineering we use all these languages to build new simulation tools to model anything from futuristic leading-edge technology to natural geological systems millions of years old.

In simple terms, computational or software engineering is the art and science of expanding the field of engineering on a computer, but the details are infinitely more complicated. Software engineers confront a range of scales beyond any other engineering practice, design codes that are seldom completely understood until the finished software product is deployed, and complexity that rivals the most intricate of real-world engineering systems. We are charged with applying the most recent advances from our high tech neighbors in California's Silicon Valley to create tools that address some of our oldest societal concerns, such as defense, transportation, resource management, and communications. At the same time, we seek to achieve economies of scale that reward the taxpayers' investments and facilitate Department of Energy collaborations.



The Electromagnetic Interactions Generalized (EIGER) code, developed by the Center for Computational Engineering, helps the Navy design modern ships. This new generation of electromagnetics code can determine where to locate advanced communication systems and how to configure them for optimum performance.

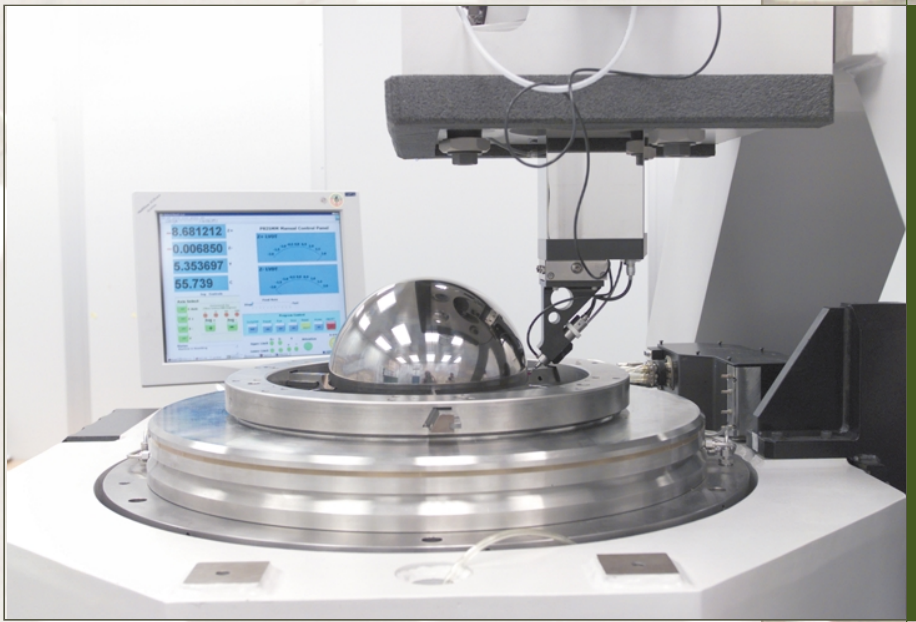
Center for Precision Engineering

At the Center for Precision Engineering we strive to offer more accuracy for less cost. The challenge, however, is that cost can skyrocket as the demand for absolute accuracy increases, the ratio of accuracy to overall size increases, or the "dimensionality" or complexity increases. Unfortunately, multiples of these demands are occurring simultaneously in a number of projects at the Laboratory. Under such circumstances, the high cost of precision manufacturing can undermine our ability to construct the experimental equipment to conduct "Big Science."

The Laboratory has long been a headliner in the field of precision engineering, starting with weapons design in the 1950s. We expect the Laboratory to continue its demand for further pioneering work in this field, relying on our expertise in the design of machines and instruments, the development of manufacturing processes, and our advanced work in dimensional metrology and systems engineering. We are applying this expertise to evolve machinery capable of atomic-level material removal and deposition. This will help us build precise parts and assemblies and employ the metrology required to characterize these parts and assemblies.

Our developing capabilities will be used to build the experimental target packages to study weapons physics on the NIF. This stretches us in two ways. Compared to the simple, two-dimensional target packages that we fielded on the NOVA laser, we can now increase the complexity by studying events in three dimensions. Alternatively, we can view this new expertise as a decrease in size and cost of between 100 to 1000 times when compared to past weapons experiments conducted at the Nevada Test Site. The ultimate challenge of the NIF is to construct complex, millimeter-size or "meso-scale" devices from exotic materials to precise tolerances in an extremely clean environment.

In 1999, we made significant progress in two areas. First, we developed a new method to help us design machines that will be used to manufacture parts with spatial-frequency-based specifications, something we do at the present only through the extensive use of rules-of-thumb. Second, we devised a method of dimensional metrology for inspecting non-rigid objects, which allows us to extract the exact shape of a part from the deformation induced in the part just by touching it.



The Precision Inspection Shell Measuring Machine measures non-rigid objects for inspecting component parts.

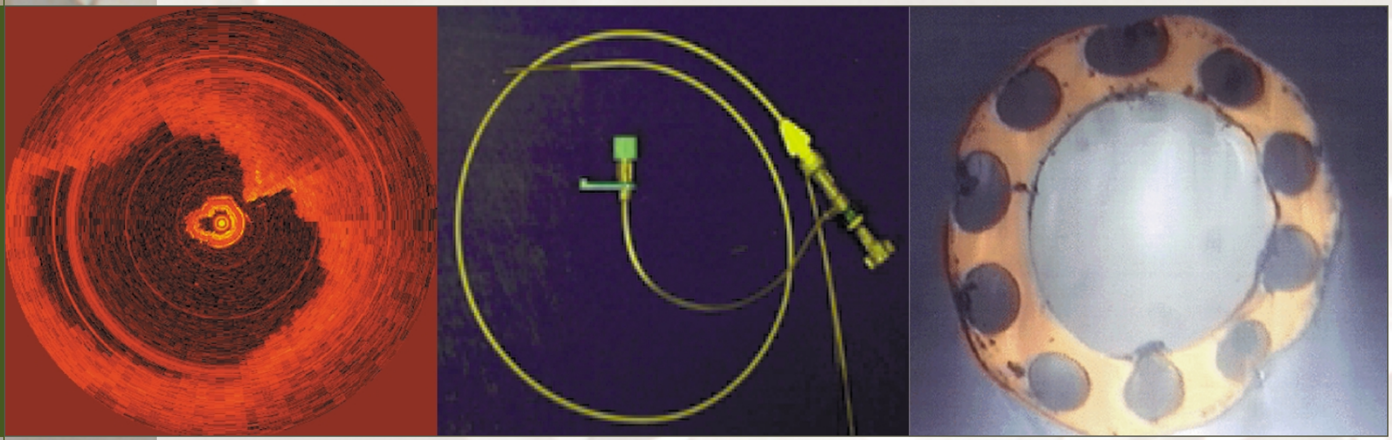
Center for Microtechnology

One in every police car. That is the long-range objective of the polymerase-chain-reaction (PCR) detector of potentially dangerous biological and chemical agents, developed by the Center for Microtechnology. The handheld device has been the subject of a recent cover article in *Popular Science* and the focus of a feature on *CBS Evening News*. Today, when terrorist groups are capable of creating lethal accidents, such as in Japan's subways, the need is obvious for a portable detector that can produce accurate results for many viruses and bacteria in seven minutes.

The PCR detector is the most well-known of the accomplishments of the Center whose mission is to invent, develop, and apply microtechnologies, in concert with Laboratory programs, to improve global security as well as advance global ecology and bioscience. Capabilities cover materials, fabrication, devices, instruments, and systems that require microfabricated parts, including microelectromechanical systems, often called MEMS. Much of the Center's work is concentrated in their microfabrication facility and revolves around boosting the array of detection and semiconductor instrumentation.

While their work is principally driven by the needs of Laboratory programs, the Center must deliver complete solutions to complex problems by teaming experts from many disciplines. The 60 Center staff members offer expertise in electronics engineering, mechanical engineering, chemical engineering, chemistry, physics, and the biosciences.

Other 1999 successes include dielectrophoresis technology for blood cells, which has been used at the MD Anderson Cancer Center to separate leukemic blood cells from healthy ones. Our Center has also improved the number of multiple wavelengths carried per fiber in optical interconnects. We have built a portable gas chromatograph that has demonstrated parts-per-billion sensitivity. Finally, the Center has collaborated with the University of California at Los Angeles to build more sophisticated wireless sensors with the intent to build a fully communicating network of sensors.



Our Center for Microtechnology has advanced the optical coherence tomography (OCT) imaging system, in collaboration with the Medical Technology Program and the Plastics and Advanced Composites Facility. Left: The OCT system was used to take an* in vivo *image of a pig artery. Center: The multi-lumen catheter prototype provides integrated imaging capabilities without obstructing the catheter's central lumen. Right: The multi-lumen catheter tubing has inner-wall lumens for optical fiber and actuator integration.

Center for Nondestructive Characterization

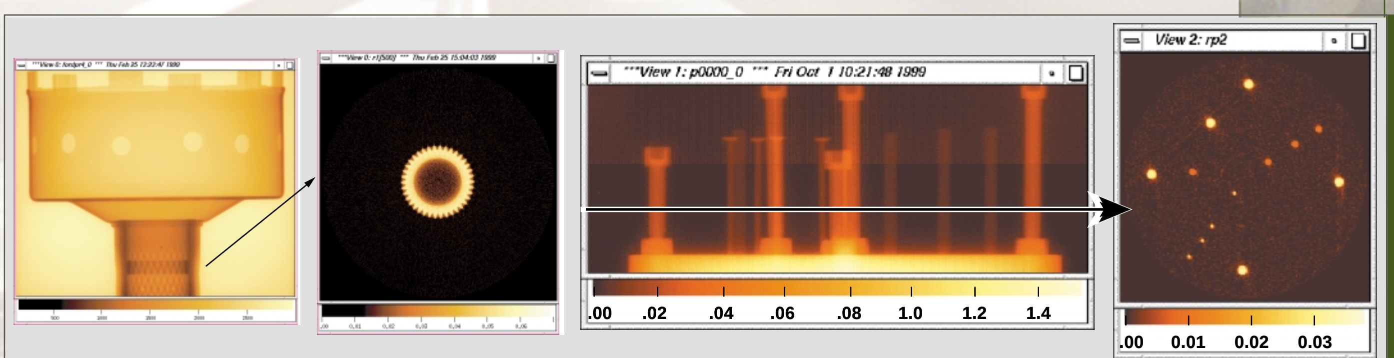
Every day in every airport technology quickly scans millions of suitcases for weapons and other dangerous items without damaging the suitcases. The same occurs in hospitals where x-rays or magnetic resonance imaging technology enables doctors to peer into bodies nonintrusively. Nondestructive characterization does the same job of analysis, but in this field the scanning is performed for highly potent contents like radioactivity—where neither the worker or container can be compromised.

Today our Center for Nondestructive Characterization is advancing technologies that characterize materials at the beginning of the process when new materials are being developed and at the end of the process when parts must be safely disposed of or properly reused. It is being called a dual front-line and end-of-the-line technology that can significantly improve certification, life prediction, life extension, reuse, and disposal of all types of materials.

In 1999, the Center concentrated on making improvements in two areas: quantitative nondestructive characterization (NDC) and fast nanoscale imaging. In quantitative NDC, engineers use nondestructive measurements to determine physical properties in three dimensions and as a function of time. For example, we use this technique to characterize lightweight materials for future automobiles. Fast nanoscale imaging allows quantitative multidimensional imaging down to nanometer-scale lengths. This technology would boost inspection of laser targets and optical glass surfaces.

This past year, these two technologies were applied to:

- Weapons system performance to provide three-dimensional measurements for advanced diagnostics
- Nuclear stockpile stewardship to better predict lifetimes
- Extraordinary laser systems to check for optics damage
- Nonproliferation, arms control, and international security to reduce the threat of mass destruction



Digital radiography (far left) and computed tomography (CT) (middle left) x-ray images are used to analyze a prototype clutch-retainer housing (by permission of Ford Motor Company, Dearborn, Michigan) with an amorphous-silicon flat panel imager. Middle right: Experimental radiographic image reveals a CT alignment phantom. Far right: Convolution back projection reconstructed experiment illustrates a CT image of the phantom.

Center for Complex Distributed Systems

Recent large earthquakes in Turkey and Taiwan have demonstrated the potential for massive destruction and loss of life—and provide another “wake-up call” to the power of similar natural disasters in the United States. Preparing huge structures like the major California bridges to survive the “shake, rattle, and roll” of the “Next Big One” and similar megaprojects drive the Center for Complex Distributed Systems.

The growth of computer power and connectivity, together with advances in wireless sensing and communication technologies, is transforming the field of complex distributed systems. Engineers, through complex computer models, can forecast how large structures like highway intersections will fare during different types of stresses. Because even small waves can cause movements that contribute to fatigue factor, the need for data-gathering and modeling is immense.

Technology today allows engineers to use large numbers of sensors with a rapid, broadband communication system to achieve high-fidelity, near-realtime monitoring of complex systems. Our current task is how to assimilate the abundant measurements into the simulation process in a way that is much more useful than the current, primarily ad hoc procedures. Then, the advanced system can spell out the best way to build the most enduring bridge of the future.

In 1999, our Center for Complex Distributed Systems improved model-based signal processing algorithms to better validate and update computer models. We also collaborated with the faculty at the University of California at Berkeley to develop massive simulation models for seismic wave propagation in the earth and the dynamic response of large bridge structures (for example, the San Francisco-Oakland Bay Bridge). Third, we developed wireless data acquisition systems that provide a practical means of monitoring the optical support structures for large systems like the NIF.

Our Center for Complex Distributed Systems uses massive simulations to model the durability of the San Francisco-Oakland Bay Bridge in response to nearby fault locations (left and middle).

Honors and Awards

The following honors and awards represent new accomplishments of Engineering personnel for 1999.

R&D 100 awards

In 1999, the Laboratory earned six of the prestigious R&D 100 Awards, considered the "Oscars" of applied research. Winners are chosen by editors of the magazine and a panel of 75 experts for products or processes that promise to change people's lives by significantly improving the environment, health care, or security. Engineering personnel (listed below) were contributors to five of the six awards.

Atomic Precision Multilayer Deposition System
Jim Folta, Fred Grabner, Gary Howe, Gary Heaton, George Wells, and Stephen Vernon

High Power Diode-Pumped Solid-State Green Lasers
Isaac Bass, Ernest Dragon, Curt Cochran, Gene Donohue, Angela Niles, and Glenn Huete

Optical Modular/Switch
Robert Stoddard and Ted Wieskamp

PEREGRINE
Dewey Garrett, Brian Guidry, and Clark Powell

Solid-State Power Source for Advanced Accelerators and Industrial Applications
Hugh Kirbie, Roy Hanks, Steve Hawkins, Craig Ollis, Brad Hickman, and Bryan Lee

Professional honors and offices

American Association of Engineering Societies: Chair
Ted Saito

Institute of Electrical and Electronics Engineers
Fellow: K. David Young; Senior Members: Barbara Campbell, Anthony Lavietes, Ray Mariella, Michael Pocha, Charles Pomernacki

American Society of Mechanical Engineers: Fellow
Charles Landram

American Vacuum Society: Board of Directors
Howard Patton

American Society of Nondestructive Testing: Board of Directors
Graham Thomas

Mexican-American Engineers and Scientists: Board of Directors
Jose M. Hernandez

R&D 100 award-winning teams are: (left) Solid-State Power Source for Advanced Accelerators and Industrial Applications, (center) PEREGRINE, and (right) Atomic Precision Multilayer Deposition System.

American Nuclear Society, Robotics and Remote Systems Division
Scott Couture, Chair; Albert Disabatino, Jr., Vice-Chair

Council of Communication Management: Board of Directors
Carol Gerich

Selected awards and honors

University of California, Davis: Marr Prize for most superior dissertation
Greg Burnett

California State Polytechnic University: Mechanical Engineering Industrial Advisory Council Charter Member and Associate Chair
Robert Addis

Appointment to Defense Advanced Projects Research Agency; two-year Washington, DC, assignment
Abraham Lee

Department of Energy: Integrated Manufacturing Predoctoral Fellowship
Deborah Krulewich

Department of Energy: Award of Excellence
Barbara Kornblum, Rose McCallen, Graham Thomas

National Science Foundation: Review Panelist, Presidential Young Investigator Award; Review Committee, Division of Undergraduate Science, Engineering, and Mathematics
Moe Dehghani

American Society of Mechanical Engineers: Co-chair, MEMS Symposium, ASME Winter Annual Meeting and International Mechanical Engineering Conference and Exposition
Jonathon Simon

American Society of Mechanical Engineers: Symposium Chairman, Thermodynamics and the Design, Analysis, and Optimization of Energy Systems; Executive Member, Advanced Energy Systems Division; Member, Evaluation Committee, Edward F. Obert Award for best paper in Thermodynamics in ASME literature
Salvador Aceves

American Society of Mechanical Engineers: Chair, ASME Summer Annual Meeting
Deepak Nath

American Society of Precision Engineers: National Selection Committee, Journal Publication Review Committee, Organizing Committee Member for Annual Meeting
Ken Blaedel

IEEE: Associate Editor Transaction on Antennas and Propagation, Chair of Steering Committee for 2004 Internal Symposium and USNC/URSI National Radio Science Meeting
Hsueh-Yuan Pao

NATO Workshop, Moscow, Investigations and Applications of Severe Plastic Deformation on Structure and Properties of Ultrahigh Carbon Steel Wire: Keynote speaker
Don Lesuer

Federal Laboratory Consortium Award for Excellence in Technology Transfer
Chris Lee

Optics and Electro-Optics Standards Committee: Chairman
Dave Aikens

Optical Society of America: 1999 Annual Meeting Chair
Chuck Thompson

The Materials Society: Symposium Organizer
Don Lesuer

Nuclear Science Symposium: Treasurer, 2001 NSS Chair
Anthony Lavietes

Ultrafast Optics Conference: Top-ranked paper
James Bonlie

Distinguished Award for Engineering Recruiting Brochure
Pam Allen, Shirley McDavid, Carol Gerich, Dennis Chan

Patents

Micromachined Chemical Jet Dispenser
Steve P. Swierkowski

Porous Silicon Structures with High Surface Area/Specific Pore Size
M. Allen Northrup, Conrad M. Yu, and Norman F. Raley

Electrochemical Formation of Field Emitters
Anthony F. Bernhardt

Optical coatings of variable refractive index and high laser-resistance from physical-vapor-deposited amorphous polymer
Robert Chow, Gary E. Loomis, Ian M. Thomas

Electrochemical Sharpening of Field Emission Tips
Anthony F. Bernhardt

Pre-converted Nitric Oxide Gas in Catalytic Reduction System
Mark C. Hsiao, Bernard T. Merritt, Bernardino M. Penetrante, and George E. Vogtlin

Catalytic Reduction System for Oxygen-Rich Exhaust
George E. Vogtlin, Bernard T. Merritt, Mark C. Hsiao, P. Henrik Wallman, and Bernardino M. Penetrante

Device for Isolation of Seed Crystals during Processing of Solution
Kenneth E. Montgomery, Natalia P. Zaitseva, James J. DeYoreo, and Russell L. Vital

Separation of toxic metal ions, hydrophilic hydrocarbons, hydrophobic fuel and halogenated hydrocarbons and recovery of ethanol from a process stream
Edward J. Kansa, Brian L. Anderson, Ananda M. Wijesinghe, Brian E Viani

Multilayer dielectric diffraction gratings
Michael D. Perry, Jerald A. Britten, Hoang T. Nguyen, Robert Boyd, Bruce W. Shore

Electrode Wells for Powerline-Frequency Electrical Heating of Soils
Harley M. Buettner, William D. Daily, Roger D. Aines, Robin L. Newmark, Abelardo L. Ramirez, and William H. Siegel

Low-cost laser diode array
Barry L. Freitas, Jay A. Skidmore

Microfabricated Therapeutic Actuators
Abraham P. Lee, Allen Northrup, Dino R. Ciarlo, Peter A. Krulevitch

Mediated Electrochemical Oxidation of Organic Wastes Using a CO(III) Mediator in a Nitric Acid-Based System
G. Bryan Balazs, Zoher Chiba, Patricia R. Lewis, Norvell Nelson, G. Anthony Steward

Electrical resistance tomography using steel cased boreholes as electrodes
William D. Daily, Abelardo L. Ramirez

Microlens Frames for Laser Diode Arrays
Jay A. Skidmore, Barry L. Freitas

Concentric Ring Flywheel with Hooked Ring Carbon Fiber Separator/Torque Coupler
Thomas C. Kuklo

Microbiopsy/Precision Cutting Devices
Peter A. Krulevitch, Abraham P. Lee, M. Allen Northrup, William J. Benett

Attachment Method for Stacked Integrated Circuit (IC) Chips
Anthony F. Bernhardt, Vincent Malba

Massively Parallel Processor Networks with Optical Express Channels
Robert J. Deri, Eugene D. Brooks III, Ronald E. Haigh, Anthony J. DeGroot

Opto-acoustic transducer for medical applications
William Benett, Peter Celliers, Luiz Da Silva, Michael Glinsky, Richard London, Duncan Maitland, Dennis Matthews, Peter Krulevich, Abraham Lee

Micromachined Electrical Cauterizer
Abraham P. Lee, Peter A. Krulevitch, M. Allen Northrup

Method and apparatus for fabrication of high gradient insulators with parallel surface conductors spaced less than one millimeter apart
David M. Sanders, Derek E. Decker

Cleaning process for EUV optical substrates
Frank J. Weber, Eberhard A. Spiller

Explosive Simulants for Testing Explosive Detection Systems
John W. Kury, Brian Anderson

Aberration-free, all reflective laser pulse stretcher
Michael D. Perry, Paul S. Banks, Brent C. Stuart, Scott N. Fochs

Micromachined electrostatic actuator
Abraham P. Lee, Gary E. Sommargren, Charles F. McConaghy, Peter A. Krulevitch

Three-dimensional charge coupled device
Alan D. Conder, Bruce K. F. Young

Microfabricated instrument for tissue biopsy and analysis
Peter A. Krulevitch, Abraham P. Lee, Allen M. Northrup, William J. Benett

Precision tip-tilt-piston actuator that provides exact constraint
Layton C. Hale

Electrical heating of soils using high efficiency electrode patterns and power phases
Harley M. Buettner

Vacuum pull down method for an enhanced bonding process
James C. Davidson, Joseph W. Balch

Rigid thin windows for vacuum application
Glenn Allyn Meyer, Dino R. Ciarlo, Richard Booth, Hao-Lin Chen, George Wakalopulos

Process for forming a porous silicon member in a crystalline silicon member
Allen M. Northrup, Conrad M. Yu, Norman F. Raley

R&D 100 award-winning teams are: (left) High Power Diode-Pumped Solid-State Green Lasers and (right) Optical Modular/Switch

Engineering Tomorrow: 2000 Priorities

In the coming year, our key challenges reflect the same priorities of 1999 but with increased emphasis on leadership within the Laboratory and in the national engineering community, as well as adherence to new, higher standards in security and safety.

Continue to deliver on all milestones safely, including the Laboratory's stretch commitments. In 2000, this will include both emphasis on project deliverables, as well as continuing significant and measurable improvements in our safety records. It will also require that we fully integrate the Engineering organization with the National Ignition Facility (NIF) project office. Here we must take the leadership role to identify needs and help the NIF project address gaps in the skill base needed to complete the procurement, installation, and integration of all NIF project deliverables.

Significantly increase Engineering's level of recognition within the national engineering community to continue to attract and retain exceptional people. With the engineering market being as tight as it has ever been, we must make an extra effort to accurately project ourselves as the organization we really are—a multidisciplinary, customer-driven organization with a tremendous breadth of technical and business competencies. We must demonstrate externally that we are consistently successful in undertaking interesting and exceptionally challenging high-technology work for a variety of government and industrial customers. Aiding in this effort in 2000 will be Ted Saito of Engineering, chair of the American Association of Engineering Societies.

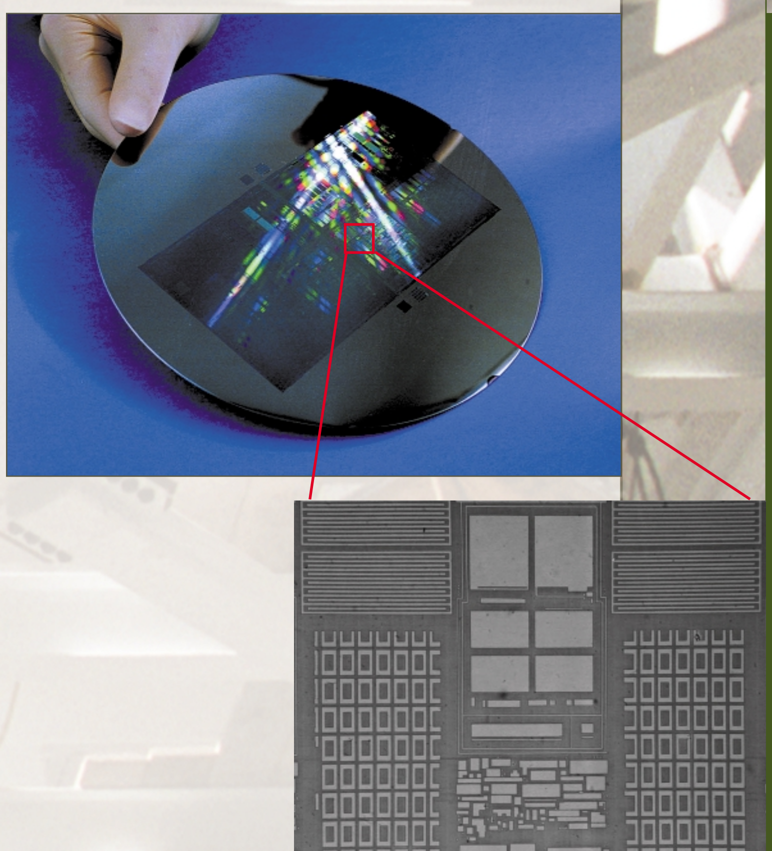
Vigorously continue the implementation of our technology strategy by constantly seeking to develop breakthrough innovations. These must solve compelling Laboratory problems that significantly expand Engineering's level of recognition nationally and fundamentally impact the way we do our business.

Increase our flexibility to position ourselves to seamlessly respond to the skills turnover of major Laboratory projects. At the same time, we must attain and sustain a wisely planned, healthy level of capital and core competency investment.

Strengthen our leadership team and fully implement a strong executive and emerging leadership program across our entire organization. In 2000, this will mean launching our Leadership Development Program for both executive and emerging leaders.

Facilitate and drive the accelerated adoption of superior project management and systems engineering practices across Engineering and the Laboratory. We have selected an established leader, with two decades of expertise in these areas, to manage this program.

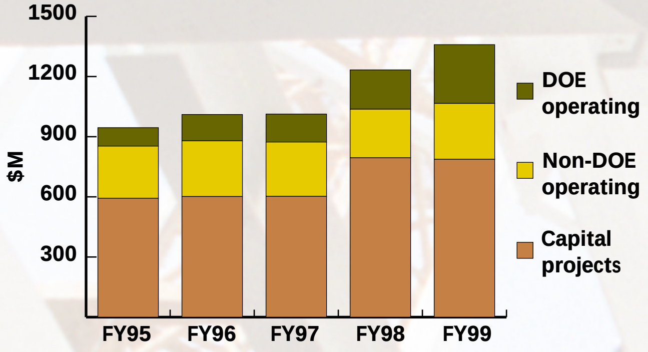
Help the Laboratory capture the next multi-hundred-million-dollar program. This means Engineering must have on board the leadership team to assume key execution roles.



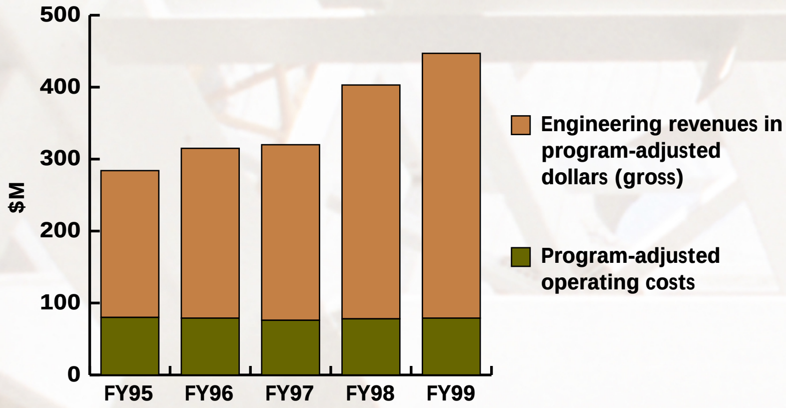
A partnership of national laboratories and a consortium of industrial partners has developed the leading technology for the next-generation, even smaller computer chip.

Appendixes: Demographics

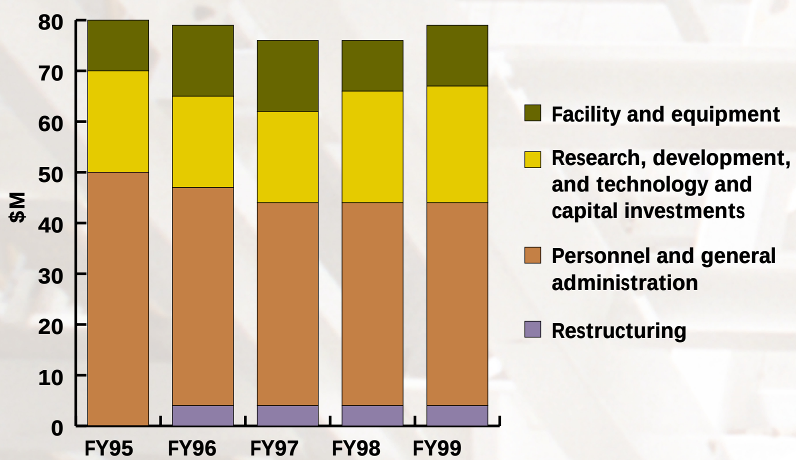
LLNL Five-Year Revenue Profile



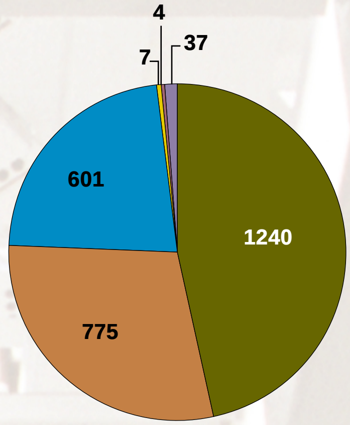
Engineering Revenue and Cost Profile



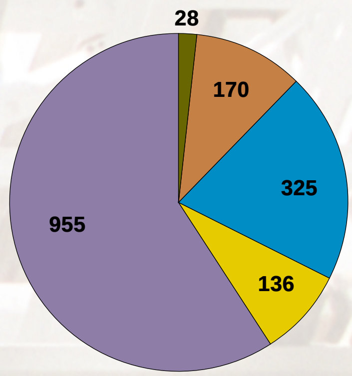
Engineering Five-Year Operating Expenses (Program-Adjusted Dollars)



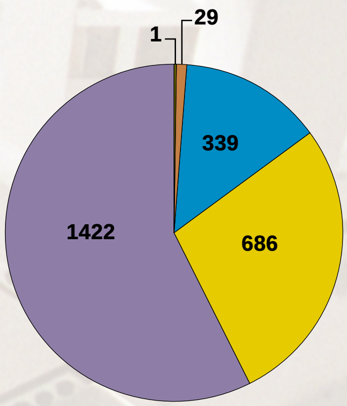
LLNL Staffing Profile (as of 12/31/99)



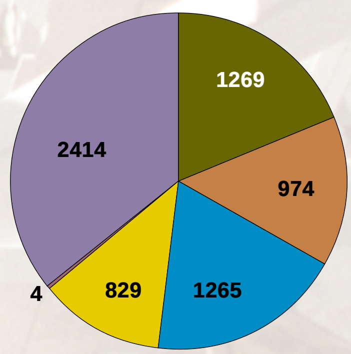
Scientists and Engineers
(2664 employees)



Administrative and Clerical
(1614 employees)



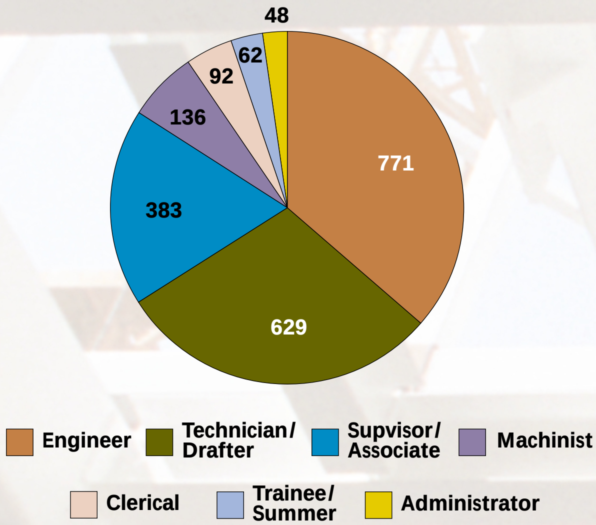
Technical and Crafts
(2477 employees)



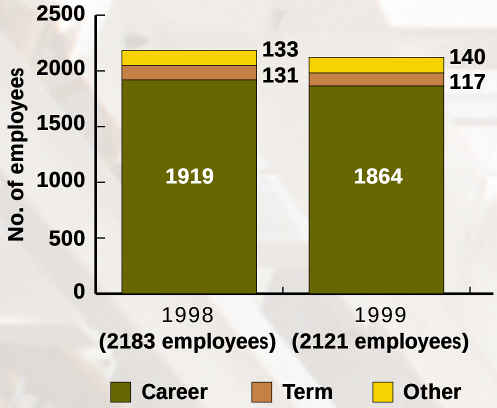
Overall
(6755 employees)

PhD MS BS AA Other None

Engineering Staffing Profile (as of 12/31/99)



Engineering Staffing Growth (as of 12/31/99)



Scientific Editor
Spiros Dimolitsas

Writer
Carol Gerich

Editor
Andrea Baron

Graphic Designer
Lucy Dobson

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The National Ignition Facility building activity involves both conventional and novel fabrication techniques.

Work performed under the auspices of the U.S. Department of Energy by the University of California Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

ENGINEERING
Lawrence Livermore National Laboratory
P.O. Box 808, L-151
Livermore, California 94551
http://www-eng.llnl.gov